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MEASUREMENTS OF H^o AND H^+ ION YIELDS DURING H^- ACCELERATION IN A 50-MeV LINAC*

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Summary

Unlike proton linacs where the only particles that can be transported are protons, an H^- linac can produce H^o and protons by stripping off one or both electrons of H^- ions during acceleration. We have measured yields of these ions as a function of linac tank pressures.

Introduction

The 50-MeV proton linac used as the injector for the ZGS has been used as the H^- injector for the Argonne Rapid Cycling Synchrotron (RCS) (30 Hz). A 50-MeV H^- charge exchange injection has been operational since 1976, and the linac operates with a pulse current of ∿5 mA, the beam pulse width of 60-120 μs, and with a repetition rate of 30 Hz. This operating condition implies that the number of the H^- ions accelerated to 50-MeV is an order of 1.3×10^{14}/s.

The binding energy of the second electron is so small that the stripping of this electron is rather easy and can happen in any point along the accelerating structure. Loss of two electrons for H^- ions has a rather small probability during the acceleration period. However, if this happens, the stripped proton can be accelerated to full energy by the linac RF buckets.

Production of these H^o and protons during the H^- acceleration can be troublesome due to the fact that these cause the background radiation when the intensity of H^- is quite high. As a matter of fact, we had to provide a special shielding arrangement near the first bending magnets of the 50-MeV H^- transport line in order to alleviate the radiation caused by the H^o and H^+ ions.

Experiment

Figure 1 shows the downstream end of the linac and the first portion of the 50-MeV transport line. In normal operating modes, the bending magnets B1 and B2 bend the H^- beam toward the RCS. The H^o ions pass straight through the line to a beam stop Faraday cup which is in the former ZGS injection line. The protons are bent opposite to the H^- line and buried in the bending magnet, B1, which has some additional shieldings. Beam toroid, BT, measures the output current of the linac.

For the H^o yield measurement, we placed a thin, stainless foil, 5 mil thick, about 1 m upstream of the beam stop Faraday cup. For the proton yield measurement, we have reversed the polarities of the B1 and B2 bending magnets and transport the protons to another Faraday cup located about 5 m downstream in the transport line. The output H^- current of the linac is read by the beam toroid.

The range of the linac pressure variation was obtained by shutting off various linac vacuum pumps. As the linac tank pressure rises, the yield reading and vacuum reading were performed simultaneously.

Figure 2 shows the ratios of H^o and H^+ to H^- currents exiting the linac. The H^- current we had during the experiment was 5.5 mA. The lines shown in the figure were obtained by a linear least-squares fit.

"Apparent" charge changing cross sections can be calculated by using $I(H^o \text{ or } H^+) = I(H^-)n\sigma L$, where n is the number of residual gas molecules per cubic centimeter at a given vacuum pressure, and L is the length

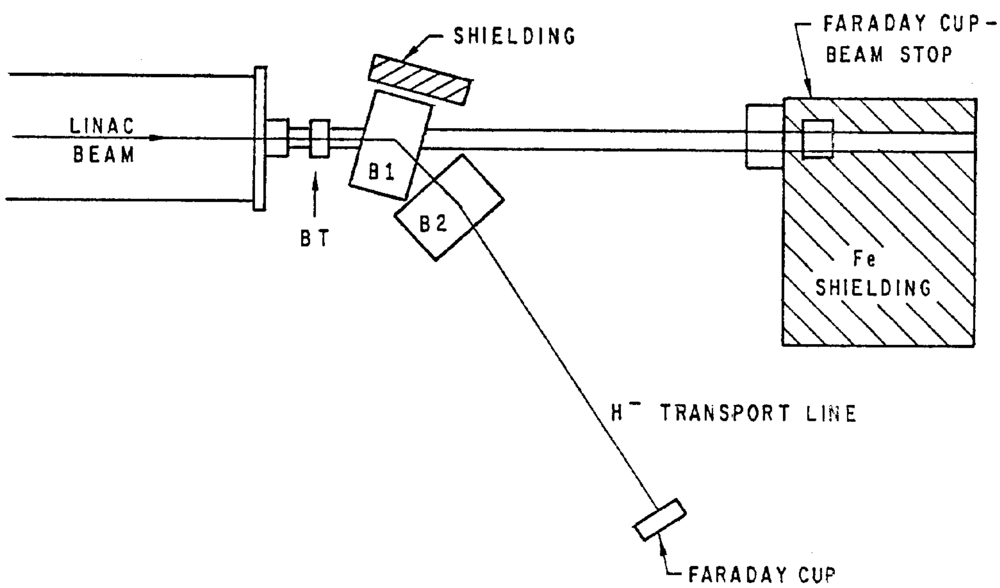

Figure 1.

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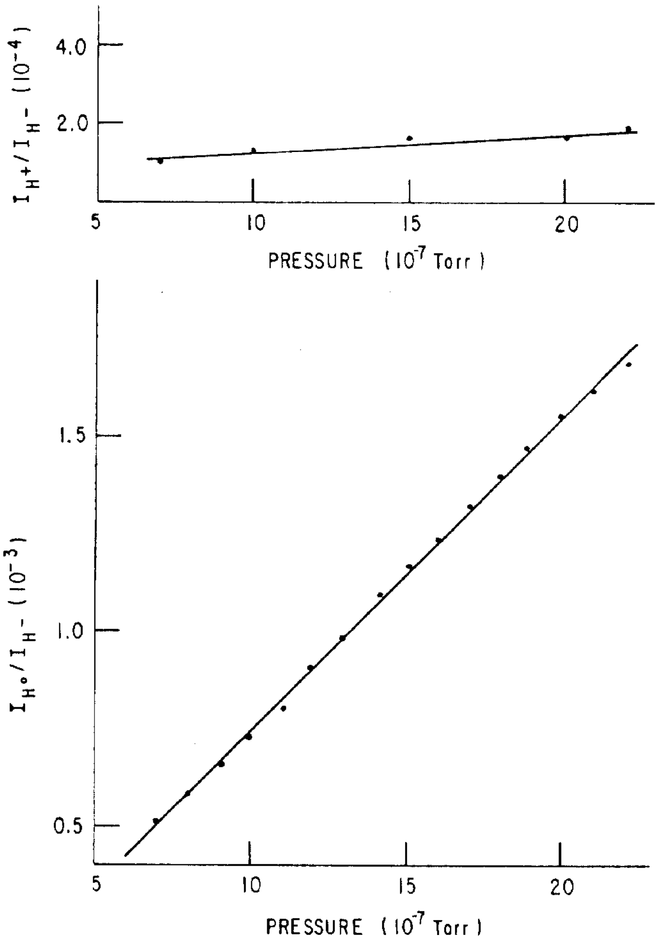

Figure 2

of the linac. The cross section can also be calculated by using the slopes of the output currents versus the pressure.

Results and Discussion

It should be emphasized that what we have measured are apparent charge changing cross sections averaged over an energy range from a few MeV to 50-MeV. Although the injection energy from the ion source was 750-keV, since we had a stripper of 5 mil thick stainless steel, the cut-off energy could be 2-MeV. Furthermore, the charge exchanges occurring at an early part of the linac may not reach the detector located downstream of the linac due to a smaller, solid angle sustained by the detector, as well as the betatron motion of the particles being accelerated. In order to take into account all these effects, an elaborate Monte-Carlo calculation is being planned.

Thus, with the above presumptions, we have calculated the "apparent" cross section for H^0 production by the H^- ions in the linac vacuum to be $(0.82 \pm 0.09) \times 10^{-17}$ cm^2 per molecule, and the "apparent" cross section for H^+ production by the H^- ions to be $(0.45 \pm 0.33) \times 10^{-18}$ cm^2 per molecule.

The sum of the above two cross sections is about a factor of four smaller than a theoretical calculation done by G.H. Gillespie.[1] The theoretical cross section averaged over 3-MeV to 50-MeV would be 3.6×10^{-17} cm^2/N_2.

Acknowledgment

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References

1. George H. Gillespie, Phys. Rev. A16, 943 (1977).